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Takahashi et al.

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(54) **DISPLAY DEVICE HAVING AN ANTENNA AND METHOD OF MANUFACTURING SAME**

(75) Inventors: **Yuji Takahashi**, Kawasaki (JP); **Toru Ozaki**, Kawasaki (JP); **Masanobu Hatanaka**, Kawasaki (JP); **Hirohisa Naito**, Kawasaki (JP); **Takahiro Kii**, Kawasaki (JP); **Kazumi Kubota**, Kawasaki (JP); **Akira Miyazaki**, Kawasaki (JP); **Takefumi Horie**, Kawasaki (JP); **Kiyohiko Ikeda**, Kawasaki (JP)

(73) Assignee: **Fujitsu Limited**, Kawasaki (JP)

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H01L 21/18 (2006.01)
H01L 33/00 (2010.01)
H01Q 1/06 (2006.01)

(52) **U.S. Cl.**
USPC **257/88**; 343/702; 343/720; 343/721; 438/34; 438/59

(58) **Field of Classification Search**
USPC 343/702, 720, 721; 257/88; 438/34, 438/59; 362/253; 445/24
See application file for complete search history.

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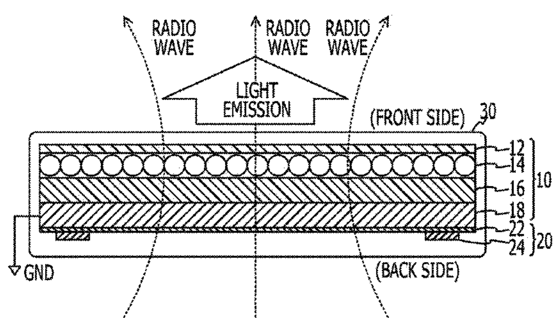
Primary Examiner — Jarrett Stark
(74) *Attorney, Agent, or Firm* — Fujitsu Patent Center

(57) **ABSTRACT**

A display device and a method of manufacturing the same, the display includes: an electrode plate operable to have a radio-frequency wave to pass therethrough; a light-emitting portion disposed in a direction of one surface of the electrode plate, the light-emitting portion including the electrode plate serving as a back electrode; and an antenna disposed in a direction of another surface of the electrode plate, the antenna having a stripline structure or a microstrip line structure and using a potential of the electrode plate as a reference potential.

18 Claims, 10 Drawing Sheets



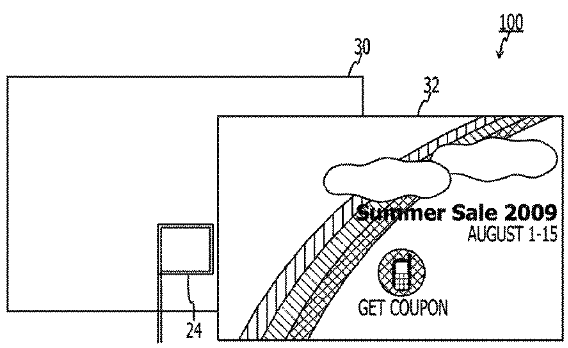


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FIG. 1

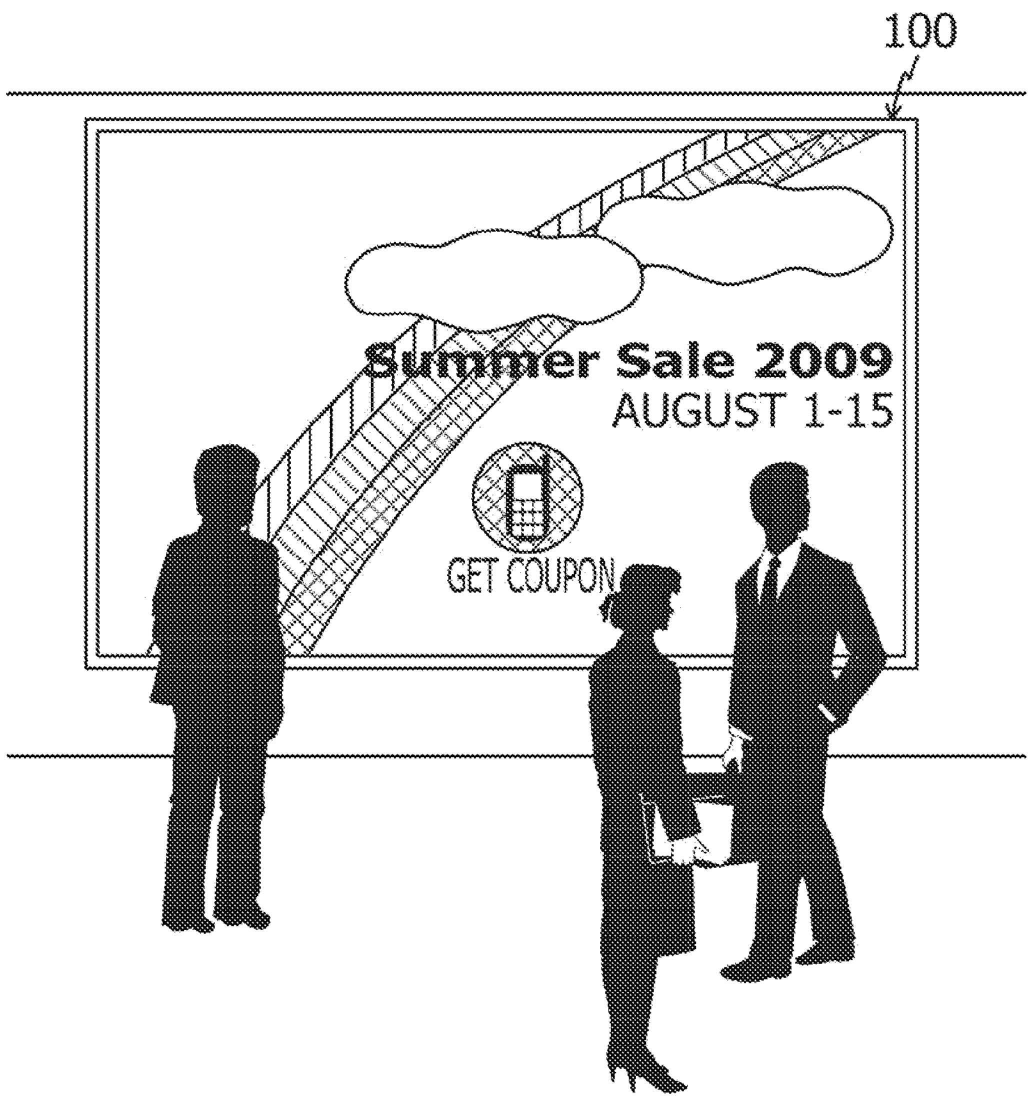


FIG. 2

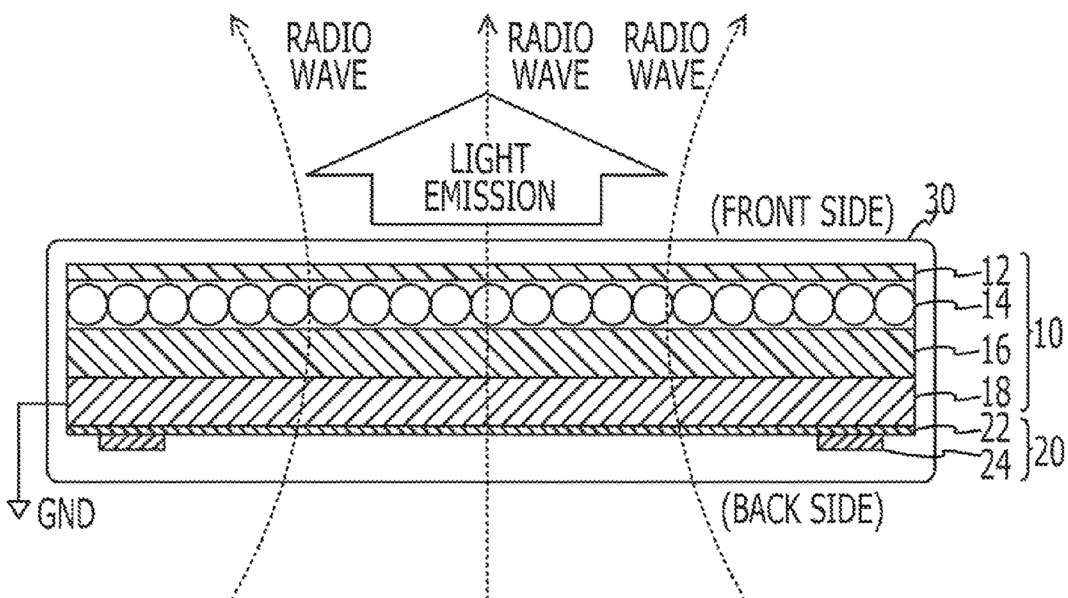

RADIO WAVE
RADIO WAVE
RADIO WAVE
LIGHT EMISSION
(FRONT SIDE)
30
12
14
16
18
10
22
24
20
GND
(BACK SIDE)

FIG. 3

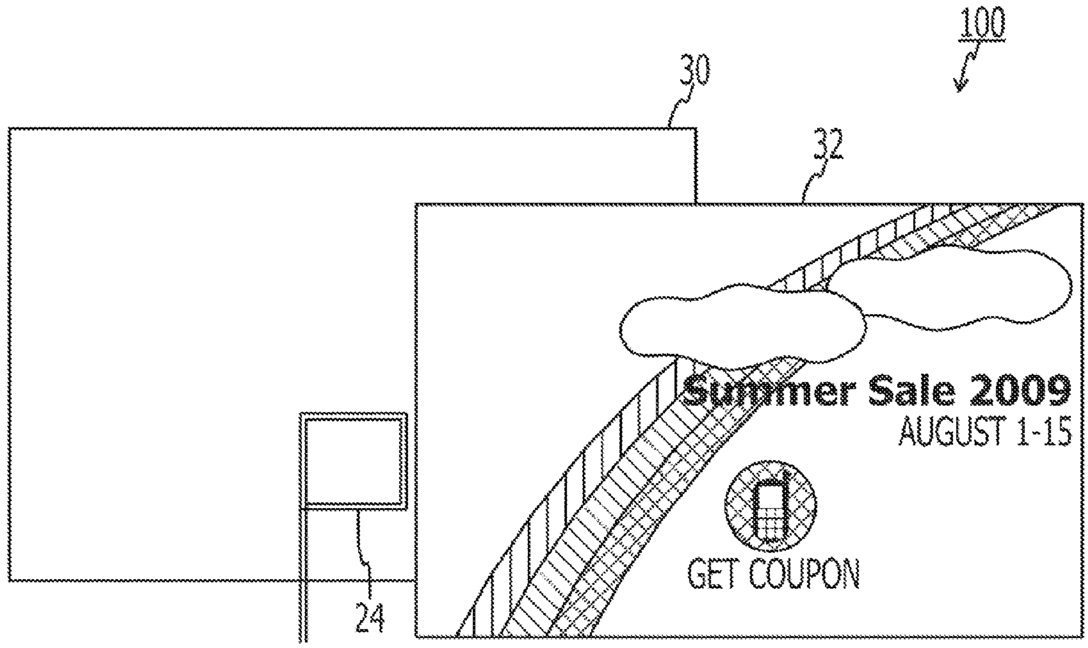


FIG. 4

ELECTRODE MATERIAL	VOLUME RESISTIVITY (Ω·m)	TRANSMISSIVE PROPERTY
COPPER	1.72×10^{-8}	×
SILVER	1.62×10^{-8}	×
CARBON	1.38×10^{-3}	O
ITO	$0.2\sim0.4\times10^{-5}$	O

FIG. 5

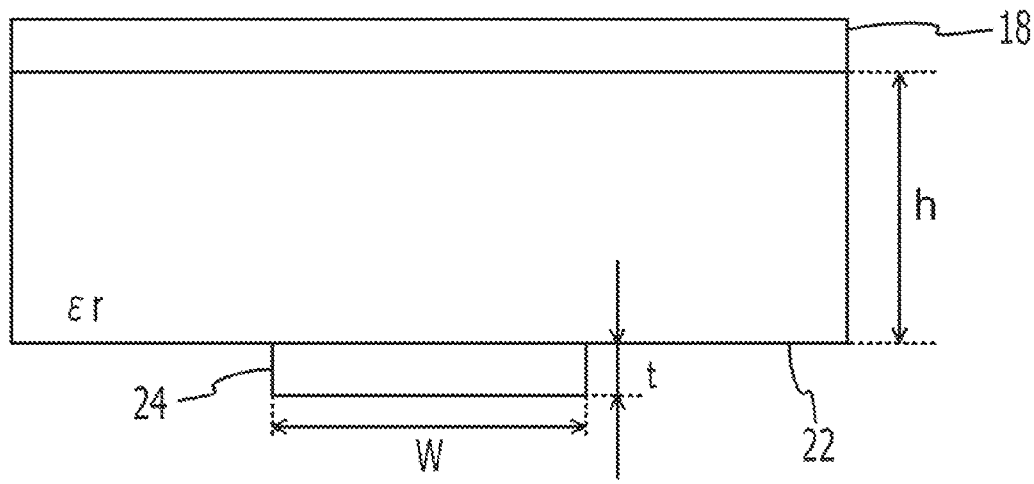


FIG. 6

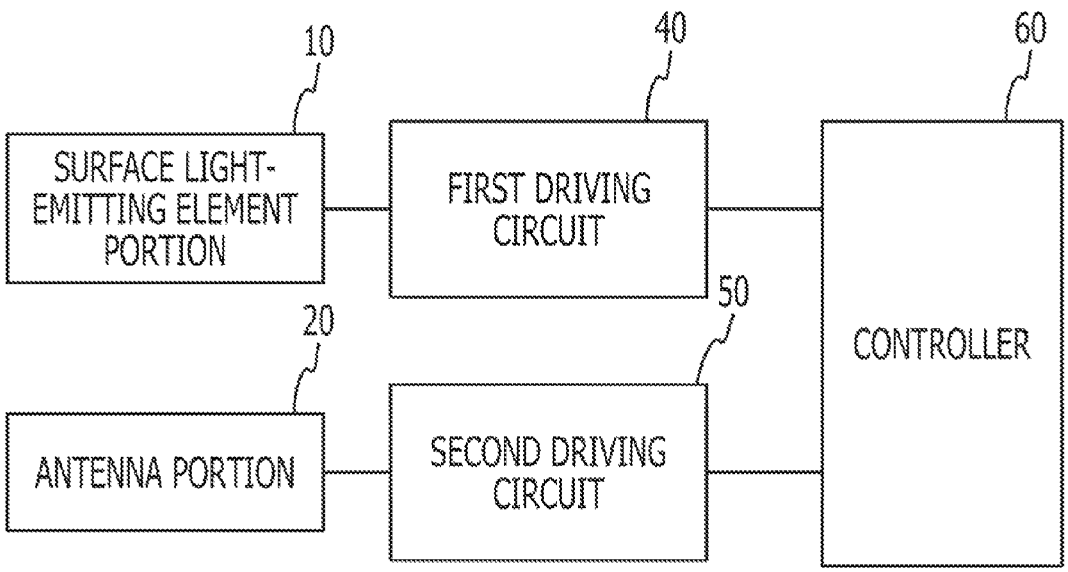

10
40
60
SURFACE LIGHT-EMITTING ELEMENT PORTION
FIRST DRIVING CIRCUIT
50
CONTROLLER
20
ANTENNA PORTION
SECOND DRIVING CIRCUIT

FIG. 7

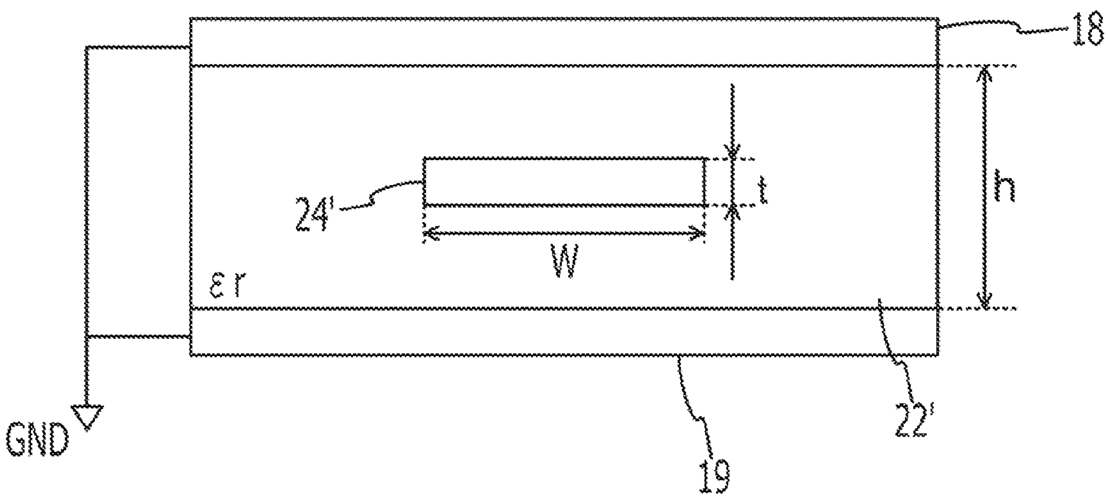


FIG. 8

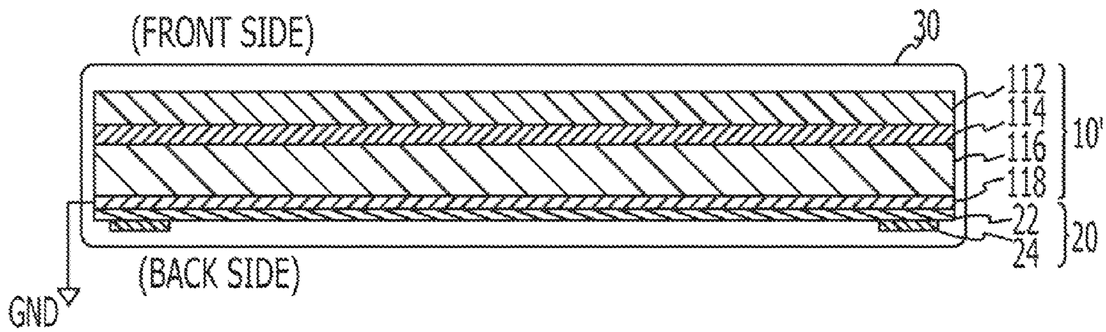


FIG. 9

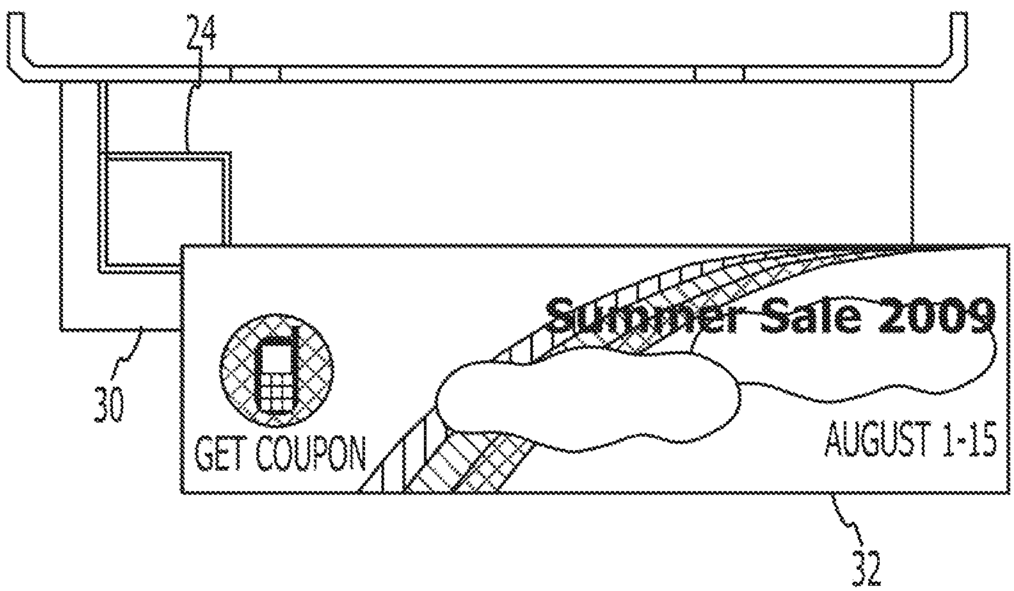
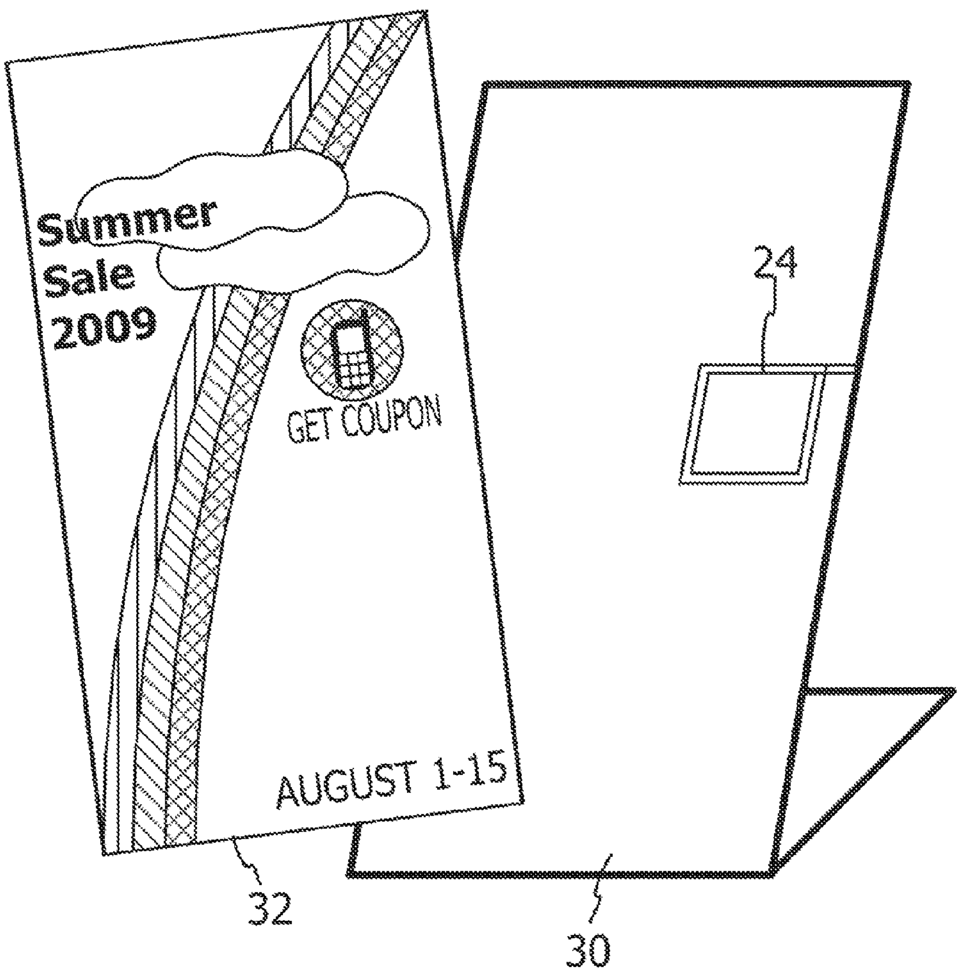


FIG. 10



DISPLAY DEVICE HAVING AN ANTENNA AND METHOD OF MANUFACTURING SAME

CROSS-REFERENCE TO RELATED APPLICATION

This application is based upon and claims the benefit of priority of the prior Japanese Patent Application No. 2009-209631, filed on Sep. 10, 2009, the entire contents of which are incorporated herein by reference.

FIELD

The embodiments discussed herein are related to display device shaving antennas and a method of manufacturing the same.

BACKGROUND

Services are increasing that are based on data communication carried out between contactless integrated circuit (IC) cards (such as SUICA™, EDY™ (provided by bitWallet, Inc. in Japan and a brand of prepaid type digital cash service), and ID™) and external terminals (such as readers/writers) therefor using radio waves. Each of such contactless IC cards includes a loop antenna and an IC. Radio frequency (RF) (e.g., 13.56 MHz) is used by services of this type.

Mobile phones having functions of the contactless IC cards are also emerging. In addition to the functions of the contactless IC cards, such mobile phones have the following functions. Upon being placed over readers/writers installed near large advertising media, such as large posters placed on a street, the mobile phones can send text messages and display web sites on display screens thereof. Such functions attract attention as new advertising mechanisms.

For example, Japanese Laid-open Patent Publication No. 2004-157499 discloses a reader/writer that is installed near a large poster placed in a public space to attract attention. The reader/writer transmits information matching a content of the large poster. As large advertising media replaces large posters, the practical use of paper-thin light-emitting elements, such as an organic electroluminescence (EL) and an inorganic EL, is underway.

SUMMARY

According to an aspect of an embodiment, a display device and a method of manufacturing the same includes: an electrode plate operable to have a radio-frequency wave to pass therethrough; a light-emitting portion disposed in a direction of one surface of the electrode plate, the light-emitting portion including the electrode plate serving as a back electrode; and an antenna disposed in a direction of another surface of the electrode plate, the antenna having a stripline structure or a microstrip line structure and using a potential of the electrode plate as a reference potential.

The object and advantages of the invention will be realized and attained by elements, features, and combinations particularly pointed out in the claims.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** depicts a usage example of a display device;

FIG. **2** depicts an example of a cross section of the display device;

FIG. **3** depicts an example of arrangement of a sheet and an antenna electrode;

FIG. **4** is a table illustrating volume resistivity of copper, silver, carbon, and indium tin oxide (ITO) and whether copper, silver, carbon, and ITO allow a radio wave to pass therethrough;

FIG. **5** schematically depicts a microstrip line structure;

FIG. **6** depicts an example of a control system of the display device;

FIG. **7** schematically depicts a stripline structure;

FIG. **8** depicts an example case of adopting an organic EL serving as a surface light-emitting element portion;

FIG. **9** depicts a first modification of the usage example of the display device; and

FIG. **10** depicts a second modification of the usage example of the display device.

DESCRIPTION OF EMBODIMENTS

In the figures, dimensions and/or proportions may be exaggerated for clarity of illustration. It will also be understood that when an element is referred to as being "connected to" another element, it may be directly connected or indirectly connected, i.e., intervening elements may also be present. Further, it will be understood that when an element is referred to as being "between" two elements, it may be the only element layer between the two elements, or one or more intervening elements may also be present.

Problems involving an arrangement of a reader/writer adjacent to a large advertising medium will be discussed.

(1) Problem with Positions of Large Advertising Medium and Reader/Writer

As depicted in FIG. 3 of Japanese Unexamined Patent Application Publication No. 2004-157499, a direction in which a user looks at a large advertising medium may deviate from a direction of a reader/writer. Accordingly, the user may overlook the reader/writer.

(2) Problem with Integration of Thin Advertising Medium and Reader/Writer

Since an existing reader/writer has a thickness of approximately 50 mm, the thickness of an integrated device increases depending on the thickness of the reader/writer even if an advertising medium is paper-thin (approximately 1 mm).

Problems involving integration of an antenna into an advertising medium will now be discussed.

(1) Problem with Quality of Displayed Advertisement Affected by Antenna Wiring Visible to Users

For example, when a sheet of a light-emitting element, such as an organic EL or an inorganic EL, is used as an advertising medium, antenna wiring is arranged preferably on a foreground of the advertising medium for better communication performance. However, antenna wiring arranged in the foreground may block light emitted by the light-emitting element to degrade quality of the displayed advertisement.

(2) Problem with Length of Antenna Wiring

When an advertising medium includes an antenna, a length of wiring between a driving circuit and the antenna increases in proportion to the size of the advertising medium. In such a case, an increase in resistance of the wiring connected to the antenna may cause mismatching of impedance between the antenna and the driving circuit. Communication may fail because of the impedance mismatching. For example, when an inductance D of wiring that is 2 mm in width, 0.1 mm in thickness, and 100 mm in length is equal to 83 nanohenries (nH), an impedance Z at a frequency of 13.56 MHz generally used by contactless IC cards and readers/writers can be represented as Equation (1):

$$Z = 2\pi f D = 2\pi \times 13.56 \times 10^6 \times 83 \times 10^{-9} = 7.072\ \Omega \tag{1}$$

when the antenna is arranged along four sides of a B0-size (1030 mm×1456 mm. The B0-size is a standard of paper that provides with Japanese Industrial Standards (JIS). The B0 size is a size whose total of about four is 4972 mm.) sheet of a light-emitting element, the length of the wiring is up to (1030 mm+1456 mm)×2=4972 mm. In such a case, the impedance Z is equal to 351.6Ω. Since the impedance of the antenna increases in proportion to the length of the wiring, impedance mismatching between the antenna and a circuit connected to the antenna (i.e., a signal generating source) may be inevitable.

A display device **100** according to an embodiment for solving such problems will be described in detail below based on FIGS. **1-6**.

FIG. **1** depicts a usage example of the display device **100**. As depicted in FIG. **1**, the display device **100** which may be installed at passages of transportation stations and on walls of commercial facilities displays advertisements of products and events to passersby.

The display device **100** has, for example, a structure depicted in an example of a cross-sectional view of FIG. **2**. For example, the display device **100** includes, for example, a surface light-emitting element portion **10** serving as a light emitter, an antenna portion **20** serving as an antenna, and a package portion **30** for substantially enclosing the surface light-emitting element portion **10** and the antenna portion **20**. The package portion **30** may be made of a material, such as polyethylene terephthalate (PET), that is waterproof. As depicted in FIG. **3**, for example, an advertisement-printed sheet **32** having optical transparency is adhered on a surface (e.g., an upper surface in FIG. **2**) of the package portion **30**. The advertisement may also be printed directly on the surface of the package portion **30** without the sheet **32**.

Referring back to FIG. **2**, the surface light-emitting element portion **10** has a thickness of approximately 1 mm and includes a transparent electrode **12**, a light emitter layer **14**, a dielectric layer **16**, and a back electrode **18** serving as an electrode plate. The transparent electrode **12** is made of, for example, indium tin oxide (ITO). The transparent electrode **12** may be made of a transparent conductive film, such as indium zinc oxide (IZO). The light emitter layer **14** includes particles of an inorganic fluorescent material, such as copper-doped zinc sulfide (ZnS:Cu), dispersed in an organic binder. Other than ZnS:Cu, the light emitter layer **14** may use manganese-doped zinc sulfide (ZnS:Mn). The light emitter layer **14** determines luminance and luminous efficiency of the surface light-emitting element portion **10**. The inorganic fluorescent particles in the light emitter layer **14** determine the color of light emitted by the light emitter layer **14**. For example, when ZnS:Cu is used as the inorganic fluorescent particles, the color of the light emitted by the light emitter layer **14** is blue-green. For example, when ZnS:Mn is used as the inorganic fluorescent particles, the color of the emitted light is orange.

The dielectric layer **16** includes ferroelectrics, such as barium titanate ($BaTiO_3$), dispersed in an organic binder. The back electrode **18** is connected to ground. FIG. **4** depicts, as a table, volume resistivity of each material, i.e., copper (Cu), silver (Ag), carbon (C), and ITO, and whether the material allows a radio wave to pass therethrough (transmissive property). As depicted in FIG. **4**, carbon and ITO have a volume resistivity not as small as that of copper and silver and allow a radio wave to pass therethrough. Accordingly, the back electrode **18** is preferably made of carbon or ITO in this embodiment. With such a configuration, each of the transparent electrode (ITO) **12**, the light emitter layer (ZnS:Cu) **14**, the dielectric layer ($BaTiO_3$) **16**, and the back electrode (carbon or ITO) **18** of the surface light-emitting element portion **10** allows a radio wave to pass therethrough. Thus, in accordance with this embodiment, the surface light-emitting element portion **10** allows a radio wave to pass therethrough.

To allow a radio wave to pass therethrough, the back electrode **18** may be made of a material having a volume resistivity larger than $1.0\times10^{-6}\ \Omega\cdot m$. Accordingly, other materials having such a volume resistivity may be used to form the back electrode **18**.

The surface light-emitting element portion **10** having such a configuration emits light in response to application of 1-kHz alternating voltage of approximately ±100 V across the transparent electrode **12** and the back electrode **18** by an alternator, not depicted, included in a surface-light-emitting-element-portion driving circuit (hereinafter, referred to as a first driving circuit) **40** (see FIG. **6**). Since the sheet (advertisement) **32** adhered on the surface of the package portion **30** is illuminated by the emitted light, visibility of the advertisement can be improved.

As depicted in FIG. **2**, the antenna portion **20** includes, for example, a dielectric layer **22** and an antenna electrode **24**. The dielectric layer **22** also serves as a protection layer and is preferably made of, for example, medium of paint or pigment ink in an embodiment. The antenna electrode **24** is made of silver (Ag), for example. As depicted in FIG. **3**, at least part of the antenna electrode **24** is in a loop shape. In FIG. **3**, the loop of the antenna electrode **24** is arranged at a position corresponding to a part of the sheet **32** displaying an image of a mobile phone (e.g., a part displaying an image "GET COUPON"). As depicted in FIG. **2**, the antenna portion **20** shares the back electrode **18** with the surface light-emitting element portion **10**. Since the back electrode **18** is connected to ground, a microstrip line structure is realized. As depicted in FIG. **2**, the antenna portion **20** transmits an RF wave (e.g., 13.56 MHz) from the back side and to the front side. Since the surface light-emitting element portion **10** has a property for allowing a radio wave to pass therethrough as described above, the radio wave generated by the antenna electrode **24** is transmitted outside (to the front side) through the surface light-emitting element portion **10** in this embodiment. This radio wave can be received by users' mobile phones. According to the embodiment, communication can be successfully carried out with mobile phones using the antenna portion **20** disposed on the back side of the surface light-emitting element portion **10**. Additionally, the antenna portion **20** disposed on the back side does not block light emitted by the surface light-emitting element portion **10**.

Advantages adoption of the microstrip line structure in the antenna portion **20** will now be described.

Dimensions of the microstrip line are defined as depicted in FIG. **5**. For example, a width and a thickness of the antenna electrode **24** are denoted as W and t, respectively. A thickness (i.e., height from the back electrode **18**) and a relative dielectric constant of the dielectric layer **22** are denoted as h and C_r, respectively. In such a case, an impedance Z_o can be represented as Equation (2).

$$Z_0 = \frac{60}{\sqrt{0.475\times\varepsilon_r + 0.67}}\ln\left(\frac{4h}{0.67(0.8W + t)}\right) \qquad (2)$$

A description will now be given for a case of adjusting the impedance Z_0 to match impedance (50Ω herein) of an antenna-portion driving circuit (hereinafter, referred to as a second driving circuit) **50** (see FIG. **6**) using this Equation, for example. When wiring made of copper (Cu) has a length of the B0 size (=4972 mm), for example, simply setting the width W, the thickness t, and the thickness h equal to 0.25 mm, 18 μm, and 100 μm, respectively, yields the impedance Z_0 equal to 50.1Ω.

Since adoption of the microstrip line allows the impedance to be easily set equal to a desired value, mismatching impedance can be avoided or at least reduced even if the wiring is long. The foregoing calculation can be executed with dedicated software.

FIG. **6** depicts an example of a control system of the display device **100**. As depicted in FIG. **6**, the control system of the display device **100** includes, for example, the first driving circuit **40** for driving the surface light-emitting element portion **10**, the second driving circuit **50** for driving the antenna portion **20**, and a controller **60** for controlling the first and second driving circuits **40** and **50**. The controller **60** controls the first driving circuit **40** when the surface light-emitting element portion **10** emits light. The controller **60** also controls the second driving circuit **50** when the antenna portion **20** transmits an RF wave. The RF wave transmitted by the antenna portion **20** can carry information related to an advertisement, e.g., URL information of a web site having coupon information in the example of FIG. **1**.

When a user is interested in an advertisement displayed on the display device **100** depicted in FIG. **1** or when the user wants the coupon, the user can acquire the URL information of the web site having the coupon information by placing their mobile phone over the displayed image "GET COUPON". In this way, the user can check details of the advertisement on a screen of their mobile phone and use the coupon.

As described above, the display device **100** according to this embodiment includes the back electrode **18** that allows an RF wave (e.g., 13.56 MHz) to pass therethrough, the surface light-emitting element portion **10** that is disposed in a direction of one surface of the back electrode **18** and includes the back electrode **18**, and the antenna portion **20** in the microstrip line structure that is disposed in a direction of the other surface of the back electrode **18** and uses potential of the back electrode **18** as reference potential thereof. Accordingly, even if the antenna portion **20** is arranged on the side of the back electrode **18** opposite to the side having the surface light-emitting element portion **10**, the antenna portion **20** can transmit a generated radio wave outside through the back electrode **18**. Since the antenna portion **20** does not block light emitted by the surface light-emitting element portion **10**, the display device **100** can maintain high display quality. Since the antenna portion **20** arranged in the direction opposite to the light-emitting direction of the surface light-emitting element portion **10** is included in the display device **100**, users can receive information from the antenna portion **20** by bringing their mobile phones near an advertisement displayed by the surface light-emitting element portion **10**. Such a configuration can decrease a likelihood that users overlook a reader/writer compared to a case where the reader/writer is installed near the advertisement as in the case of the related art and, thus, can improve usability. Furthermore, the microstrip line structure of the antenna portion **20** can make the antenna portion **20** thin and, ultimately, the display device **100** thin. The microstrip line structure also allows the impedance of the antenna portion **20** to be easily adjusted to the impedance of the second driving circuit **50**. Furthermore, since the surface light-emitting element portion **10** is formed of an inorganic EL in this embodiment, the display device **100** can be bent (flexible). Accordingly, the display device **100** can be placed on non-flat objects, such as a column.

In addition, since the back electrode **18** is preferably made of a material having a volume resistivity larger than 1.0×10^{-6}Ω·m in this embodiment, the back electrode **18** advantageously allows a radio wave to pass therethrough to the front side even if the antenna portion **20** is arranged on the back side of the back electrode **18**.

Furthermore, in this embodiment, the first driving circuit **40** for controlling driving of the surface light-emitting element portion **10** and the second driving circuit **50** for controlling driving of the antenna portion **20** allow emission of light and transmission and reception of information to be suitably executed, respectively.

Although the antenna portion **20** having the microstrip line structure has been described in the foregoing embodiment, the structure of the antenna portion **20** is not limited to this one. For example, the antenna portion **20** may have a stripline structure. FIG. **7** schematically depicts the stripline structure. As depicted in FIG. **7**, the stripline structure includes an antenna electrode **24'** disposed inside a dielectric layer **22'**. Discussion will be given, for example, for adjustment of an impedance Z_0 of the antenna portion **20** having such a structure to 50Ω as in the case of the foregoing embodiment. When wiring made of copper (Cu) has a length of the B0 size (=4972 mm), for example, simply setting a width W, a thickness t, and a thickness h equal to 58 μm, 1 μm, and 100 μm, respectively, yields the impedance Z_0 equal to 50.3Ω. Accordingly, the impedance can be easily matched.

Since the stripline structure allows the impedance to be easily set to a desired value in this way, mismatching impedance can be avoided or at least reduced even if the wiring is long.

Although not mentioned in the foregoing embodiment, the first driving circuit **40**, the second driving circuit **50**, and the controller **60** of the control system depicted in FIG. **6** may be arranged near or away from the surface light-emitting element portion **10**. For example, the controller **60** arranged at a location away from the surface light-emitting element portion **10** may remotely control a plurality of surface light-emitting element portions and a plurality of antenna portions in an integrated fashion. The controller **60** may be connected to the first and second driving circuits **40** and **50** with or without a cable. Additionally, the controller **60** may be connected to the first and second driving circuits **40** and **50** via the Internet and a local area network (LAN).

Although the loop of the antenna portion **20** (i.e., the antenna electrode **24**) is arranged at the position corresponding to the part of the sheet **32** displaying the image of the mobile phone (i.e., the part displaying an image "GET COUPON") in the foregoing embodiment, the position of the loop is not limited to this arrangement. For example, the loop of the antenna portion **20** (the antenna electrode **24**) may be arranged to cover a surface of the sheet **32**.

Although an inorganic EL is, not limitedly, used as the surface light-emitting element portion **10** of the display device **100** in the foregoing embodiment, an organic EL may be used. FIG. **8** depicts an example case where an organic EL **10'** is adopted as the surface light-emitting element portion. As depicted in FIG. **8**, the organic EL **10'** includes, for example, a glass substrate **112**, a transparent electrode **114**, a light emitter layer **116**, and a back electrode **118**. The transparent electrode **114** is made of, for example, ITO. The back electrode **118** is made of, for example, carbon or ITO just like the foregoing embodiment. The back electrode **118** may be shared with an antenna portion **20** just like the foregoing embodiment. Such a configuration allows a radio wave generated by the antenna portion **20** to be transmitted from the back side to the front side through the organic EL **10'** as in the case of the foregoing embodiment. Accordingly, the configuration can offer advantages similar to those provided by the foregoing embodiment.

Even when the organic EL is adopted as depicted in FIG. **8**, the antenna portion **20** may have the stripline structure depicted in FIG. **7**.

Although application of the display device **100** to large posters placed at stations has been described in the foregoing embodiment, the application of the display device **100** is not limited to this example. For example, as depicted in FIG. **9**, the display device **100** can be applied to an advertisement placed in a train or a bus. The display device **100** can also be applied to a billboard as depicted in FIG. **10**. In such cases, the antenna electrode **24** may be arranged at a position corresponding to a part displaying an image of a mobile phone or may be arranged to cover the advertisement or the billboard.

The above-described embodiments are preferable examples for carrying out the present invention. However, the present invention is not limited to the embodiments and can be variously modified without departing from the spirit of the present invention.

All examples and conditional language recited herein are intended for pedagogical purposes to aid the reader in understanding the invention and the concepts contributed by the inventor to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions, nor does the organization of such examples in the specification relate to a showing of the superiority and inferiority of the invention. Although the embodiments of the present inventions have been described in detail, it should be understood that the various changes, substitutions, and alterations could be made hereto without departing from the spirit and scope of the invention.

What is claimed is:

1. A display device, comprising:

an electrode plate operable to have a radio-frequency wave pass therethrough;

a light-emitting portion disposed in a direction of one surface of the electrode plate, the light-emitting portion including the electrode plate serving as a back electrode; and

an antenna disposed in a direction of another surface of the electrode plate, the antenna having a stripline structure or a microstrip line structure and using potential of the electrode plate as reference potential.

2. The display device according to claim **1**, wherein the electrode plate has a volume resistivity larger than 1.0×10^{-6} $\Omega\cdot$m.

3. The display device according to claim **1**, further comprising:

a light-emitter driving controller configured to control driving of the light-emitting portion; and

an antenna driving controller configured to control driving of the antenna.

4. The display device according to claim **3**, wherein the antenna and the antenna driving controller constitute at least part of an apparatus for exchanging information with an external terminal.

5. The display device according to claim **1**, further comprising:

a dielectric layer positioned between the light-emitting portion and the electrode plate.

6. The display device according to claim **1**, further comprising:

a package portion enclosing the electrode plate, the light-emitting portion, and the antenna.

7. The display device according to claim **1**, wherein the light-emitting portion includes any one of copper-doped zinc sulfide (ZnS:Cu) and manganese-doped zinc sulfide (ZnS:Mn).

8. The display device according to claim **1**, further comprising:

a transparent electrode attached to the light-emitting portion.

9. The display device according to claim **1**, wherein the transparent electrode includes any one of indium tin oxide (ITO) and indium zinc oxide (IZO).

10. The display device according to claim **1**, wherein the antenna includes an antenna electrode.

11. A method of manufacturing a display device comprising:

providing an electrode plate that allows a radio-frequency wave to pass therethrough;

disposing a light emitter in a direction of one surface of the electrode plate, the light emitter including the electrode plate serving as a back electrode;

disposing an antenna in a direction of another surface of the electrode plate, the antenna having a stripline structure or a microstrip line structure; and using a potential of the electrode plate as reference potential.

12. The method according to claim **11**, further comprising:

setting an impedance of the antenna to a predetermined value.

13. The method according to claim **11**, further comprising:

providing a light-emitter driving controller configured to control driving of the light emitter; and

providing an antenna driving controller configured to control driving of the antenna.

14. The method according to claim **13**, wherein the antenna and the antenna driving controller constitute at least part of an apparatus for exchanging information with an external terminal.

15. The method according to claim **11**, further comprising:

positioning a dielectric layer between the light emitter and the electrode plate.

16. The method according to claim **11**, further comprising:

substantially enclosing the electrode plate, the light emitter, and the antenna.

17. The method according to claim **11**, further comprising:

attaching a transparent electrode to the light emitter.

18. The method according to claim **11**, further comprising:

providing the antenna with an antenna electrode.

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